DEFINING, EXPRESSING, AND USING CONTEXT IN A SIMULATION ENVIRONMENT

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ABSTRACT: *"Reuse" and "interoperability" are two keywords in the mantra of the modeling and simulation community. In order to achieve these goals, one must be able to capture, express, and manage the context of individual entities, models, and applications. Capturing the context requires having a thorough understanding of what the entity, model, or application was intended to do and is able to do. While many aspects of "context" are not easily expressible in a format or language that could be understood and managed in a simulation environment, there are some aspects that can be and we will discuss how these aspects can be represented in a generalized object-oriented framework.*

1. INTRODUCTION

Webster's Dictionary defines context as "the conditions or circumstances which affect something."[1] Another way to express context is that it is the "if, ands, or buts" that define a situation. In terms of the simulation world, context represents all of the factors that are used to define the problem space being considered.

In this paper, we shall discuss the issues of what constitutes "context", how it can be expressed in simplified terms, and how it can be used. To demonstrate these concepts, we shall present examples from work performed by Argonne National Laboratory with the Dynamic Information Architecture System (DIAS).

2. FACTORS THAT DEFINE CONTEXT

Expressing the context of a problem or simulation is generally done using qualitative factors rather than quantitative ones. Also, the amount of information required to provide a full statement of the context is variable. To demonstrate this, consider the following statement of the purpose of a simulation:

> *"I am studying the characteristics of plants."*

This statement provides a minimal amount of context information – a single statement of an entity being used in the simulation, plants. This context information would be woefully inadequate for anyone to consider if they wanted to interoperate with the simulation. Now consider an expansion of the simulation purpose statement:

> *"I am studying the diurnal variability in the characteristics of plants in a tropical biosphere."*

This expanded statement has added two additional types of context information: a temporal reference (diurnal variability) and a geospatial reference (tropical.) The degree of context information is greater than before, but still not adequate to make a determination if interoperability is a possibility. Finally, consider the statement:

> *"I am studying the diurnal variability in the carbon dioxide uptake of native plants in a four hectare area of a tropical biosphere as a function of changes in precipitation over a three-year period."*

This is a nearly complete statement of the simulation context of this application. It describes:

- The <u>entities</u> that are the focus of the simulation (plants, carbon dioxide, and precipitation)
- A <u>temporal frame of reference</u> (diurnal)
- A <u>temporal range</u> (three-year period)
- A <u>geospatial frame of reference</u> (tropical)
- A <u>spatial range</u> (four hectare area)
- Key <u>driving factors</u> (changes in precipitation)

(Additional information could be provided on particular details, such as the algorithms, models, or data sources used.)

The types of context factor required to describe a simulation will vary from simulation to simulation and some of the factors, such as the spatial and temporal ranges and frames of reference, may be expressed in relative rather than absolute, or quantifiable terms. For example, logis-

tics studies analyze the issues involved in moving personnel and materiel from one point to another using terms like Ports of Embarkation (POE) and Ports of Debarkation (POD). These terms define locations where specific functions occur (i.e. loading and unloading) and changes in modes of transport (road/rail to ship/plane and ship/plane to road/rail) can occur. While POEs and PODs have actual locations in the "real" world, in the simulated world they are often treated as conceptual nodes with no explicit spatial information associated with them. In these kinds of applications, the "distance" between POEs and PODs is expressed as the amount of time required to move from one to the other point.

The temporal frame of reference can also be expressed in an abstract fashion using terms like "start to finish" or "birth to death" in which the frame of reference is defined in terms of transition states of the entities. As an example, the force mobilization model FORCEGEN analyzes the issues associated with preparing military units to be deployed. The simulation begins with units being "called-up" and continues until every unit is declared "ready to load."

The entities in a simulation may also have differing spatial and temporal ranges and frames of reference. This is demonstrated in Figure 1, which shows notational spatial frames of reference for a set of environmental objects that are used to produce surf zone forecasts. These objects are used in the Integrated Ocean Architecture, a DIAS application that is being used to integrate the oceanographic models being developed under the Integrated Ocean Project.

3. RELATIONSHIPS BETWEEN CONTEXT AND REUSE

Context information about the entities is especially critical in determining if objects can be reused from one simulation to another. There is, and has been, considerable effort to develop common object models that could be reused. One of the first efforts was the Joint Warfare Simulation Object Library[2] (JWSOL) that was funded by the Defense Modeling and Simulation Office (DMSO) in the mid 1990's. Even though the problem space was restricted to warfighting applications, it quickly became apparent that developing a common object model was not a simple task because warfighting entities can take on different roles and exhibit different behaviors. To demonstrate this, consider the different views that can be taken of a tank in a warfighting application, as shown in Figure 2, which shows a "blue" tank on a battlefield.
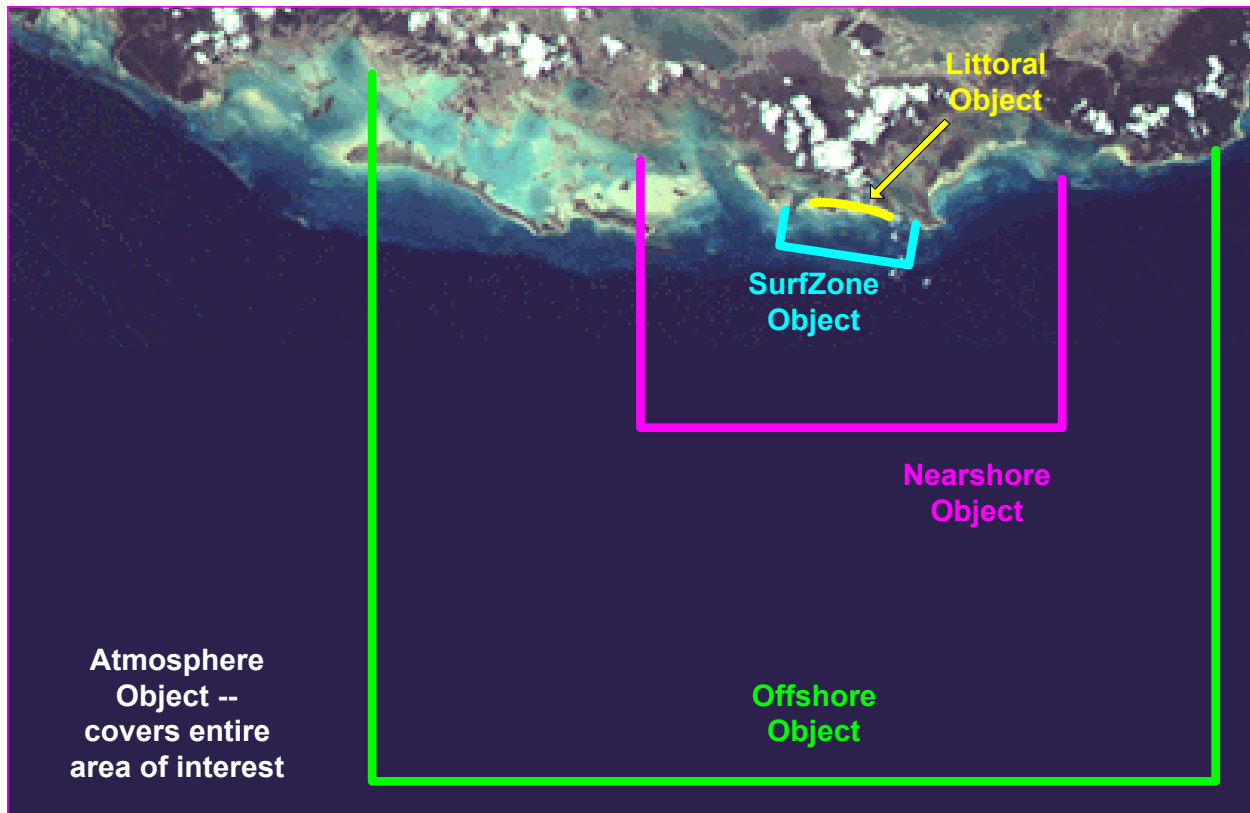

Figure 1. A Notional Representation of the Different Spatial Ranges and Frames of Reference in the Objects Used to Produce Surf Zone Forecasts in the Integrated Ocean Architecture.

There are two warfighter's views of this tank. From the "blue" perspective, the tank is an attacking weapons platform. A partial list of relevant attributes includes the types and numbers of weapons, speed, range, etc. From the perspective of "red" warfighter, the tank is something to be attacked and a primary attribute would be the tank's signature in a "red" weapon system sensor.

There are two command-related views that can be applied to the tank. To the battlefield commander, the tank is viewed as a platform to direct orders to in response to a plan or course of action (COA). From this perspective, the relevant attributes can include the position of the tank on the battlefield, the type of platform it represents, and the role it plays in the overall plan. The second command view is that of the tank commander of the tank. From the tank commander's perspective, the tank is a system of crew members and equipment to direct. Relevant attributes for this perspective can include the position of the battlefield, the state of the tank and the crew, and the plan being acted on.

Finally, the tank can be viewed from two supporting views, logistical and maintenance. To the logistician, the tank represents a piece of equipment that must be moved from point "A" to "B". The primary governing attributes for this view are the weight and size of the tank. From a maintenance perspective, the tank is an item of equipped that must be fueled, armed, and repaired.

This example demonstrates that the context(s) of the entity within the entire problem space will have an impact on the kinds of information required to describe the entity. It also demonstrates that in assessing if the entity can be reused in another application one must thoroughly understand the role and behaviors the entity exhibited in the original application and the roles it will be intended to play in the second.

4. EXPRESSING CONTEXT IN A SIMULATION

Not all aspects of context can be expressed in a form for use in simulations, but some features can be. A "Frame" object could be created to describe the spatial area of interest and the entities that operate in this area. Associated with the "Frame" object would be a "Context" object that would describe the behaviors that the objects would be able to exhibit in the simulation and the temporal extent of the simulation. An example of these objects is shown in Figure 3, which is based on work Argonne performed for the Joint Warfare System program during their prototyping effort to study the impact of the environment on vehicle mobility and the acquisition of ground targets by airborne platforms.
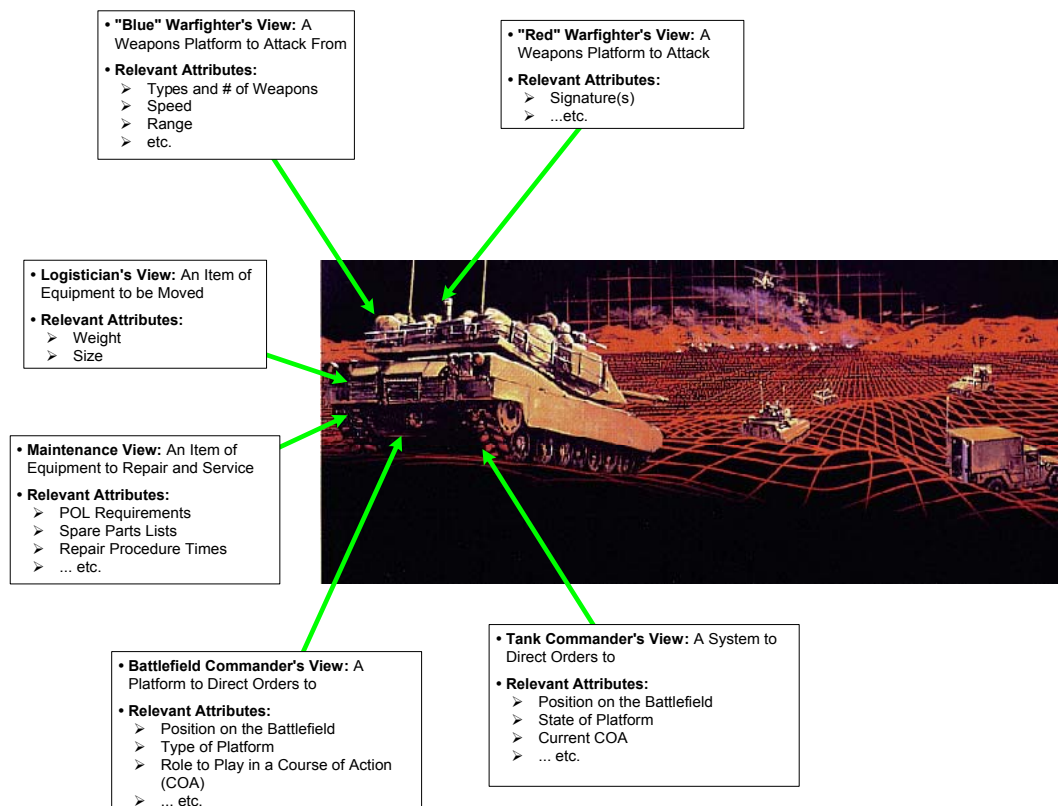

Figure 2. An Example of the Different View that can be Take of the Roles and Behavior a Tank can Perform on a Warfighting Application.

The "Frame" object contains information about three primary components: the spatial frame of reference, the spatial extent in the frame of reference, and the list of entity objects being used in the simulation frame. In the example shown, the spatial frame of reference is Bosnia and a bounding box is defined by a set of latitude-longitude points. Finally, a list of objects required for the simulation is given.

The "Context" object describes the behaviors that the entity objects can exhibit in the simulation and describes the temporal extent being performed. In the example shown, the Atmosphere object is able to "Evolve Over Time", "Obscure Line of Sight", and "Change Soil Moisture". The Atmosphere's behavior of changing the soil moisture results in the SoilCover object exhibiting the behavior of "Soil Moisture Impacts Soil Strength." The soil strength changes in the SoilCover object and the vegetation types in the SurfaceCover object contributed to the behavior of the Vehicle object of "Cover Constraints on Speed."

The example shown in Figure 3 is based on the assumption that there is a single model or algorithm being used to express each entity behavior. However, there are many instances in which there could be different models or algorithms that could be used to express an object behavior that would be a function of the a specific context factor.

To demonstrate this, consider the fundamental atmospheric behavior of radiation attenuation. There are numerous models available that could be used to calculate a measure of atmospheric attenuation and many of the common ones used in the military modeling community differ in terms of wavelength regimes that they cover, such as infrared, laser, or radar wavelengths. Figure 4 gives an example of how multiple instantiations of this behavior could be represented and the context factor that would be used to determine which form to use. The behavior of "Attenuate Radiation" is first expressed at the abstract level; i.e. not expressed by a specific model or algorithm. Then, the individual expressions of the behavior that are a function of specific wavelength regimes are given. During a simulation, a specific instantiation of the behavior that is associated with a given model or algorithm would be dynamically selected based on the wavelength regime being considered at that time.
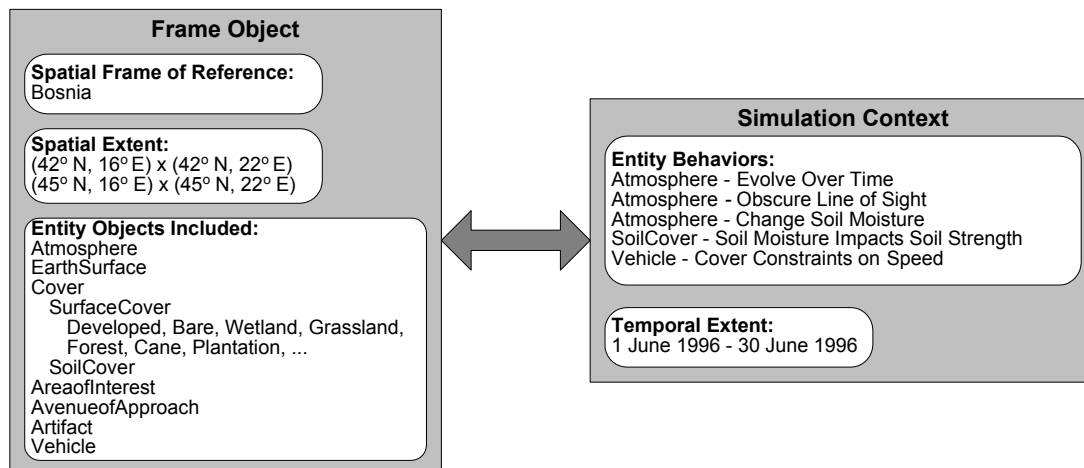
Frame Object

Spatial Frame of Reference:
Bosnia

Spatial Extent:
(42º N, 16º E) x (42º N, 22º E)
(45º N, 16º E) x (45º N, 22º E)

Entity Objects Included:
Atmosphere
EarthSurface
Cover
  SurfaceCover
    Developed, Bare, Wetland, Grassland,
    Forest, Cane, Plantation, ...
  SoilCover
AreaofInterest
AvenueofApproach
Artifact
Vehicle

Simulation Context

Entity Behaviors:
Atmosphere - Evolve Over Time
Atmosphere - Obscure Line of Sight
Atmosphere - Change Soil Moisture
SoilCover - Soil Moisture Impacts Soil Strength
Vehicle - Cover Constraints on Speed

Temporal Extent:
1 June 1996 - 30 June 1996

Figure 3. Examples of "Frame" and "Context" Objects that can be Used to Express the Simulation Context.

Simulation Context

Entity Behaviors:
Atmosphere - Evolve Over Time
Atmosphere - Attenuate Radiation
  Attenuate Visible/IR Radiation (MODTRAN)
  Attenuate Millimeterwave Radiation (RADTRAN)
  Attenuate Laser Radiation (BACKSCAT)
Atmosphere - Change Soil Moisture
SoilCover - Soil Moisture Impacts Soil Strength
Vehicle - Cover Constraints on Speed

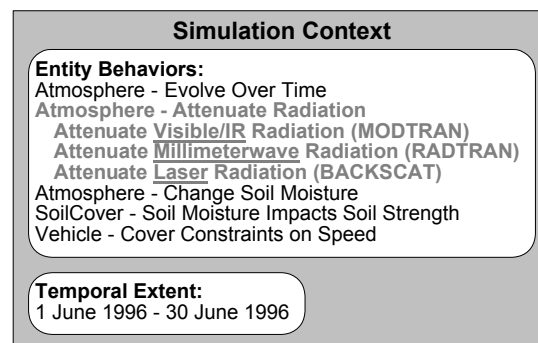Temporal Extent:
1 June 1996 - 30 June 1996

Figure 4. An Example of Multiple Instantiations of an Object's Behavior and the Context Factor that Determines Which Form Would be Used During a Simulation.

For example, attempts have been made to develop formal data dictionaries that could potentially be used in simulations. If this could be achieved, a significant aspect of the drudgery required to insure that the data passed between model components is consistent (e.g. same units and definitions) could be eliminated.

There was an effort in the SISO Synthetic Natural Environment forum to try and develop a dictionary of unique definitions that could be used for environmental applications. There was considerable spirited debate within the forum on if unique definitions could be – or should be – developed. While it was agreed that there were fundamental physics-based definitions for basic parameters, such as "temperature" or "pressure" there were different meanings to terms like "surface temperature" depending on the subject domain.

For example, to a meteorologist "surface temperature" is the temperature measured in a sheltered enclosure about 2 m above the surface, but to an engineer "surface temperature" would most likely mean the temperature of the surface. The difference between the definitions is in the spatial context of where the temperature is meant to be referenced to. In addition to having a spatial context, the parameter will most likely also have a temporal reference – does it relate to an instantaneous value or one that has been averaged over some period of time? What this example suggests is that data dictionary elements can be expressed with a fundamental physics-based definition that can be augmented with additional descriptors that define the spatial and temporal contexts.

5. RELATIONSHIP BETWEEN CONTEXT AND FIDELITY

"Fidelity" is a term with many different definitions. The Distributed Interactive Simulation (DIS) community included a set of three definitions for fidelity that is included in the DIS Lexicon. The definitions are:

1. "The similarity, both physical and functional, between the simulation and that which it simulates."

2. "A measure of realism of a simulation."

3. "The degree to which the representation with a simulation is similar to a real world object, feature, or condition in a measurable or perceivable manner."

It is very often expressed in terms of vague descriptors like "high" or "low." Understanding these terms requires knowing they are being expressed relative to. For example, a "high" resolution weather forecast model with a 1 km horizontal spatial resolution would most likely be viewed as a very low fidelity model to a cloud physicists.

Fidelity of models and simulations is most often expressed in terms of spatial and temporal factors and whether or not the simulation entities are handled discretely or in an aggregated fashion. Some of the factors that are used to describe fidelity can be quantified, but others are still only expressible in a qualitative fashion.

There is a close relationship between context and fidelity. The information used to describe the context of a simulation is also required to describe the fidelity of the simulation. However, while the context information is necessary to describe fidelity, it is not sufficient to completely describe fidelity. The reason is that fidelity requires relative measures of what the simulation is being measured against.

6. CAPTURING THE CONTEXT INFORMATION

Based on a preliminary analysis of the proposed Fidelity Framework, it appears that the information required to define context could be captured in whole, or in parts, by the Fidelity Framework. Specifically, it is felt that the portions of the framework that are shaded in Figure 5 could be used to capture context information.

7. SUMMARY

Being able to define and express simulation context is an important aspect in assessing whether one simulation's components can be reused in another simulation or if the simulation can interoperate with other simulations. The information required to define context is generally expressed using qualitative factors rather than quantitative ones.

Although not all aspects of context can be readily expressed in a form for use in simulations, some features can. For example, a "Frame" object could be created to describe the spatial area of interest and the entities that operate in the simulation. Associated with the "Frame" object would be a "Context" object that would describe the behaviors that the objects would be able to exhibit during the simulation and the temporal extent of the simulation.

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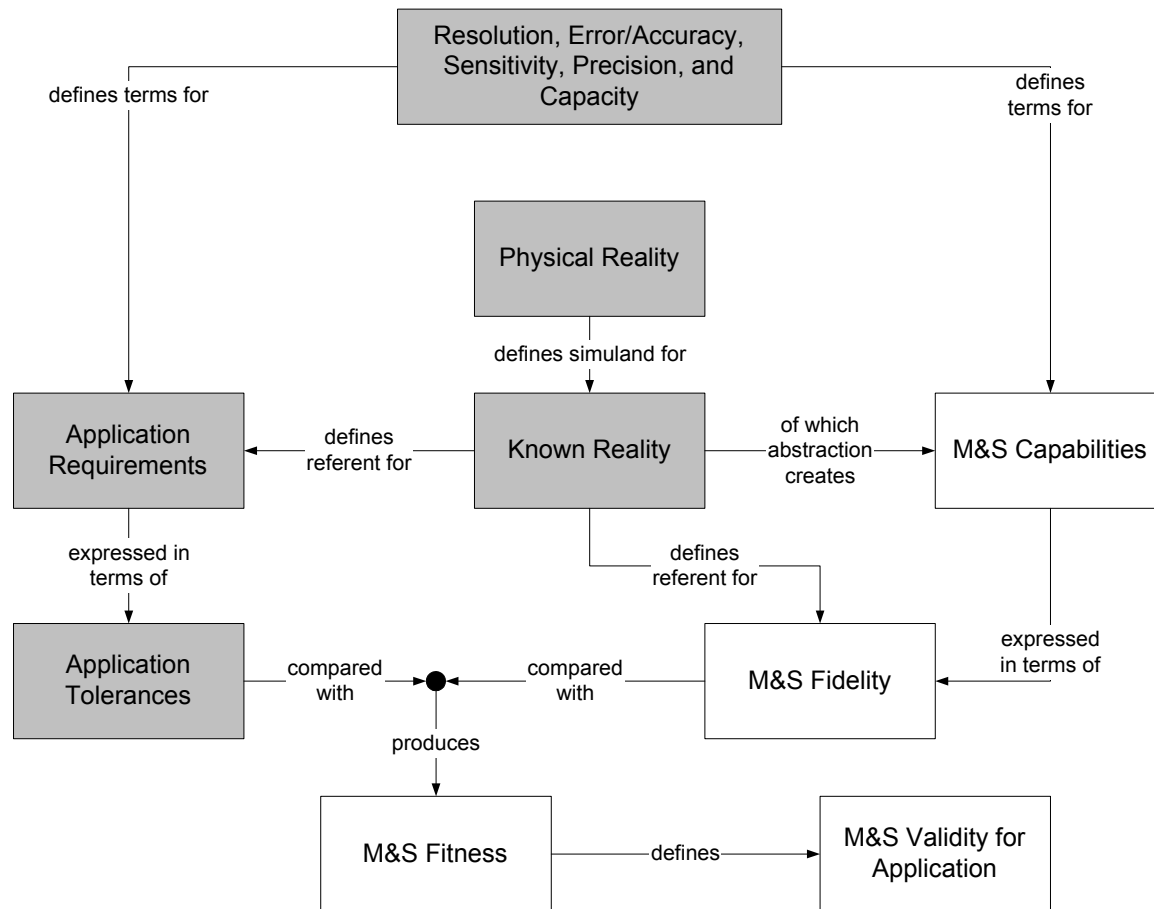
Figure 5. Representation of the Proposed SISO Fidelity Framework Noting Those Portions of the Framework that Could be used to Capture Context Information about a Simulation.

References:

[1] The New Lexicon Webster's Encyclopedic Dictionary of the English Language, Deluxe Edition, Lexicon Publications, Inc., New Yor, NY, 1989, p211.

[2] C. L. Conwell, "Joint Warfare Simulation Object Library," Technical Document 2808, Naval Command, Control and Ocean surveillance Center, RDT & E Division, San Diego, CA, 92152-5001